Final Talk

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Riverside Feb 2004

I could have said nothing about everything
But decided to say something about a few subjects of personal interest

1. Physics Argument for a Factory
2. An observation at Lab G
3. Congratulations to MTA
4. Weak focus cooling ring progress
5. Electron model FFAG
6. Target Experiment at CERN
7. Study 2a
8. Conclusion

1) Physics Argument for a Factory

Discussion: Super-Beam vs. Factory

- **Conventional/Super Beams:**
  $p + C \rightarrow \pi_{High\ E} \rightarrow \bar{\mu} + \nu_\mu$

- **Neutrino Factories:**
  $p + Hg \rightarrow \pi_{Low\ E} \rightarrow \mu_{Low\ E} \rightarrow \mu_{High\ E} \rightarrow e + \nu_\mu + \bar{\nu_e}$

For θ_{13} or CP

- **Conventional/Super Beams:** $\nu_\mu \rightarrow \nu_e$
  - **ID** — **e shower and no μ**
  - **Detector:** — **water or light plates**
  - **Background:** — **ν_e's and NC π^o's** $\approx 10^{-2}$ **for low E**

- **Neutrino Factories:** $\nu_e \rightarrow \nu_\mu$
  - **ID** — **wrong sign μ**
  - **Detector:** — **Thin magnetized Fe plates or Liquid A**
  - **Background:** — **Misidentified sign** $\approx 10^{-4}$ **for high E**

Event Rates for fixed L/E (dependence on L/E later)

- **Conventional/Super Beams:** $\nu_\mu \rightarrow \nu_e$

$$\frac{n_\nu}{W_p \ \ (\mathrm{MW})} \propto \frac{n_\nu}{n_p \ E_p} \propto \frac{n_\pi \ (\mathrm{High\ E})}{n_p} \frac{1}{E_p} \approx \frac{\mathrm{constant}}{\mathrm{E}_\nu}$$

$$\sigma \propto E_\nu \ \ \mathrm{so} \qquad \frac{n \ \mathrm{interactions}}{W_p \ \ (\mathrm{MW})} \approx \mathrm{constant}$$

- **Neutrino Factories:** $\nu_e \rightarrow \nu_\mu$

$$\frac{n_\nu}{W_p \ \ (\mathrm{MW})} \approx \frac{n_\nu}{n_p} \frac{1}{E_p} \propto \frac{n_\pi \ (\mathrm{Low\ E})}{n_p} \frac{1}{E_p} \approx \mathrm{constant}$$

$$\sigma \propto E_\nu \ \ \mathrm{so} \qquad \frac{n \ \mathrm{interactions}}{W_p \ \ (\mathrm{MW})} \propto E_\nu$$

Summary of Comparison

- **Backgrounds to Oscillation**

  For 20 GeV Factory $\ll$ Super-beam
  Low Energy Factory not so Good

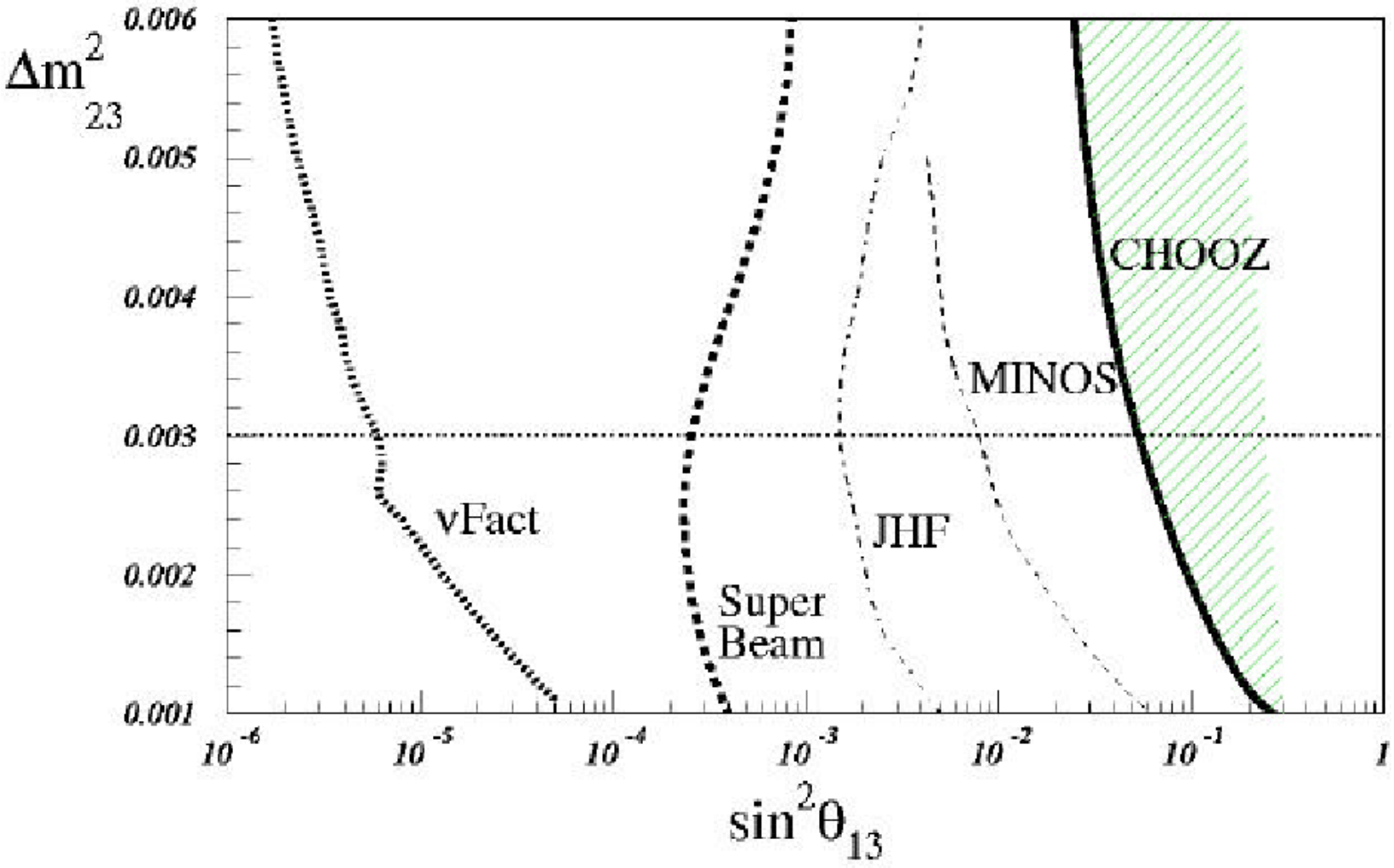
- **Neutrino Rates/Beam MW**

  For $>$20 GeV Factory $>$ Super-beam
  Low Energy Factory not so good

SO

- **If** $\sin^2\theta_{13} \ll 10^{-2}$
  then background makes conventional beams hopeless
  and the Factory is the only hope to see CP
- **If** $\sin^2\theta_{13} \geq 10^{-2}$
  then Factory not needed initially
  And it is open question whether a Factory is ever required

e.g. Limit on Theta(13) vs. Mass Difference

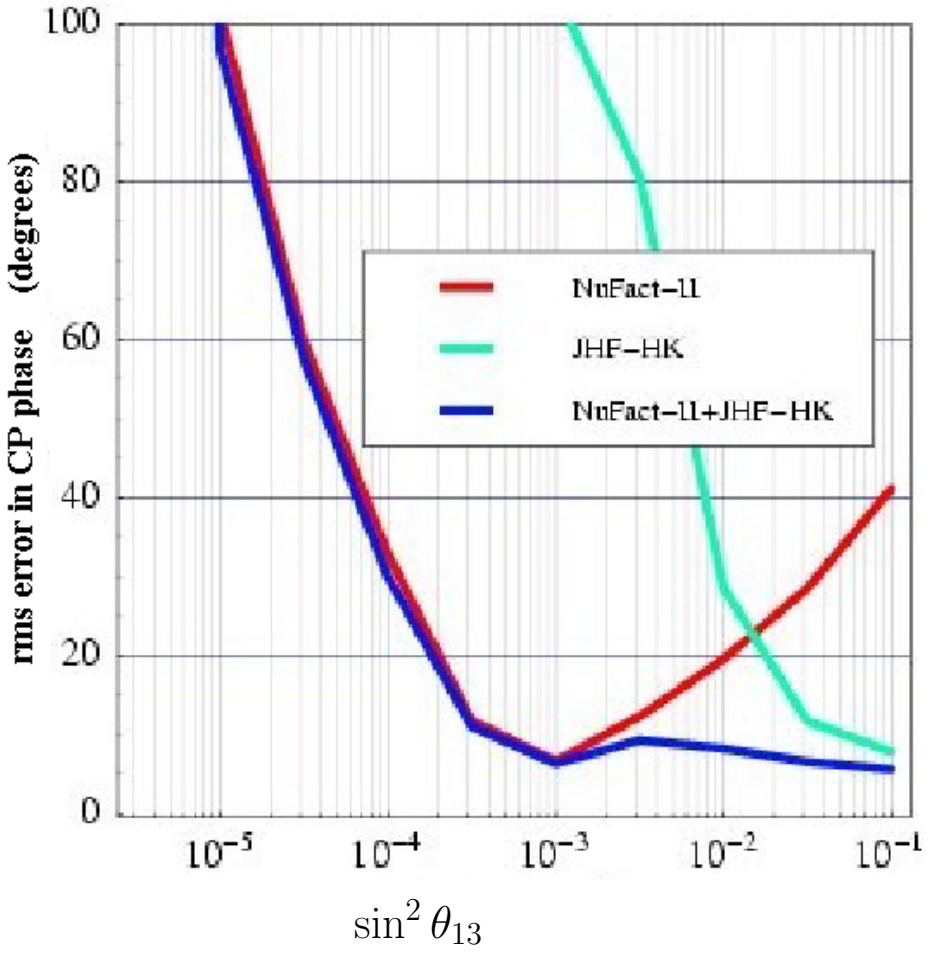


e.g. Precision of CP Determination

If $\sin^2\theta_{13} < 0.01$ then it will be hard to observe CP violation But, clearly, a Super beam will preceed a Neutrino Factory and $\sin^2\theta_{13}$ must first be determined

e.g. CERN Report: Hubner, Lindner & Winter (HEP-PH/020432)

Assuming $\delta_{\rm CP} = 90$ degrees and LMA I



Dependence on L/E (For fixed neutrino flux)

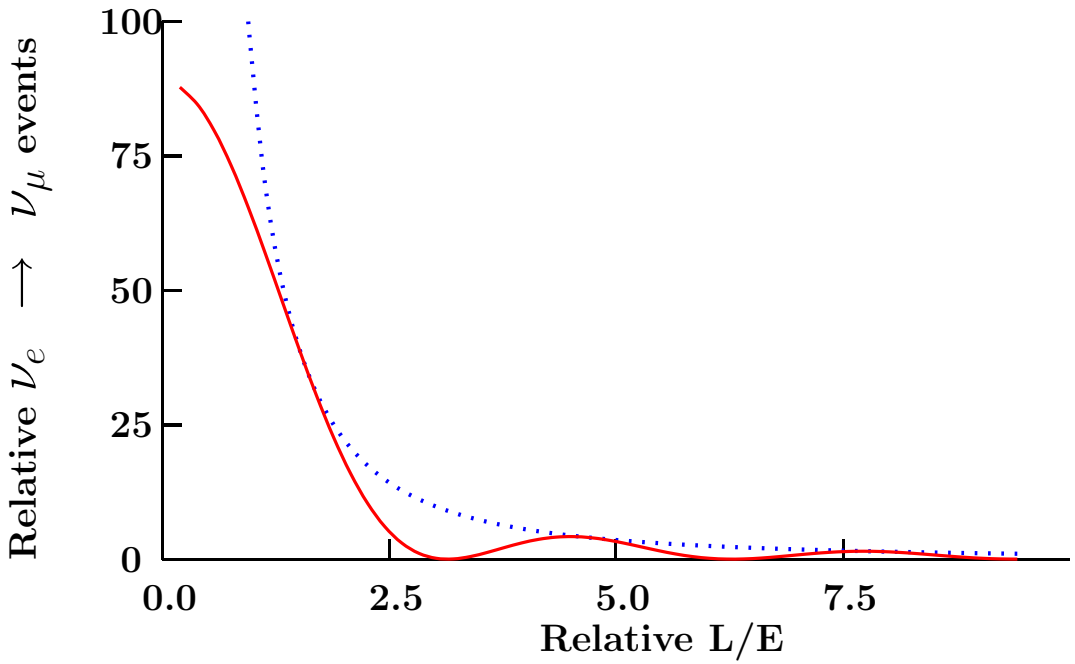
$$\text{Rate}(\nu_\mu \to \nu_\mu) \propto \underbrace{\frac{1}{L^2}}_{\text{solid angle}} \qquad E^2 = \underbrace{\left(\frac{1}{L/E}\right)^2}_{\text{production cone}}$$

$$\text{Rate}(\nu_e \to \nu_\mu) \propto \left(\frac{1}{L/E}\right)^2 \sin^2\left(\text{const} \times \frac{L}{E}\right)$$

For θ_{13}
Low L is best

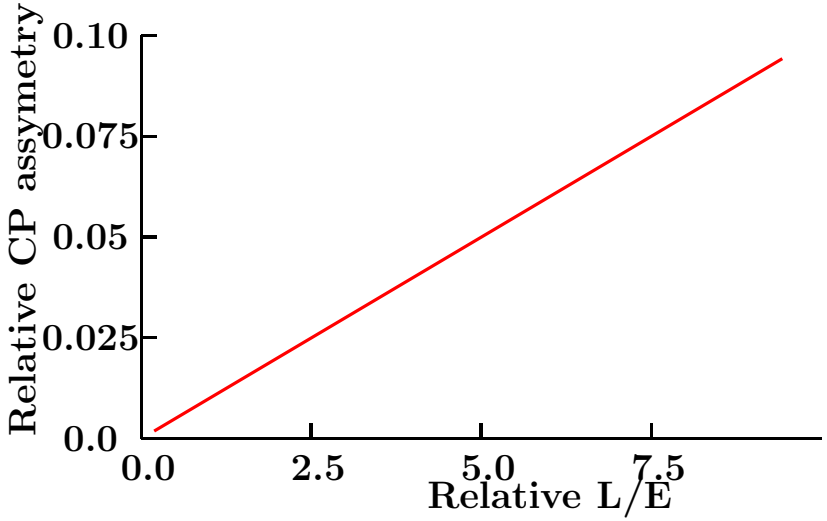
But for heierachy
Need some finite L

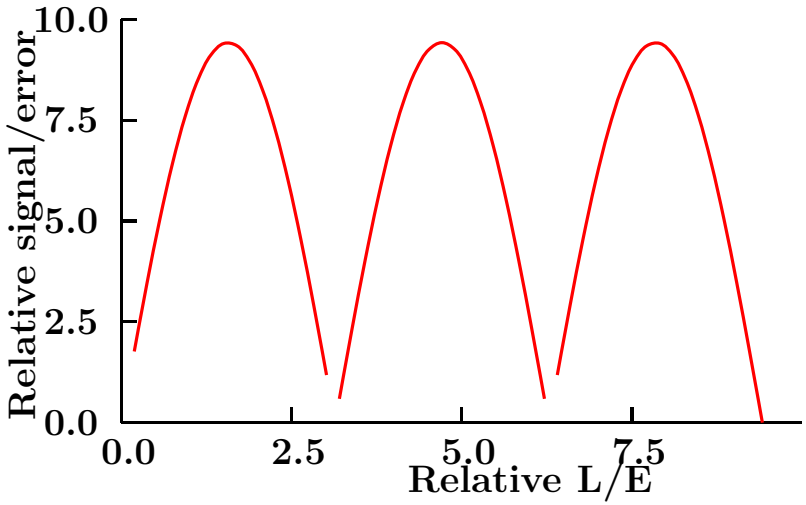
High E is fine



The Marciano Argument

CP assymetry $\nu/\bar{\nu}$ is proprtional to L





So long as θ_{13} is large enough to have a signal:
(Assymetry / statistical error) is same for any oscillation

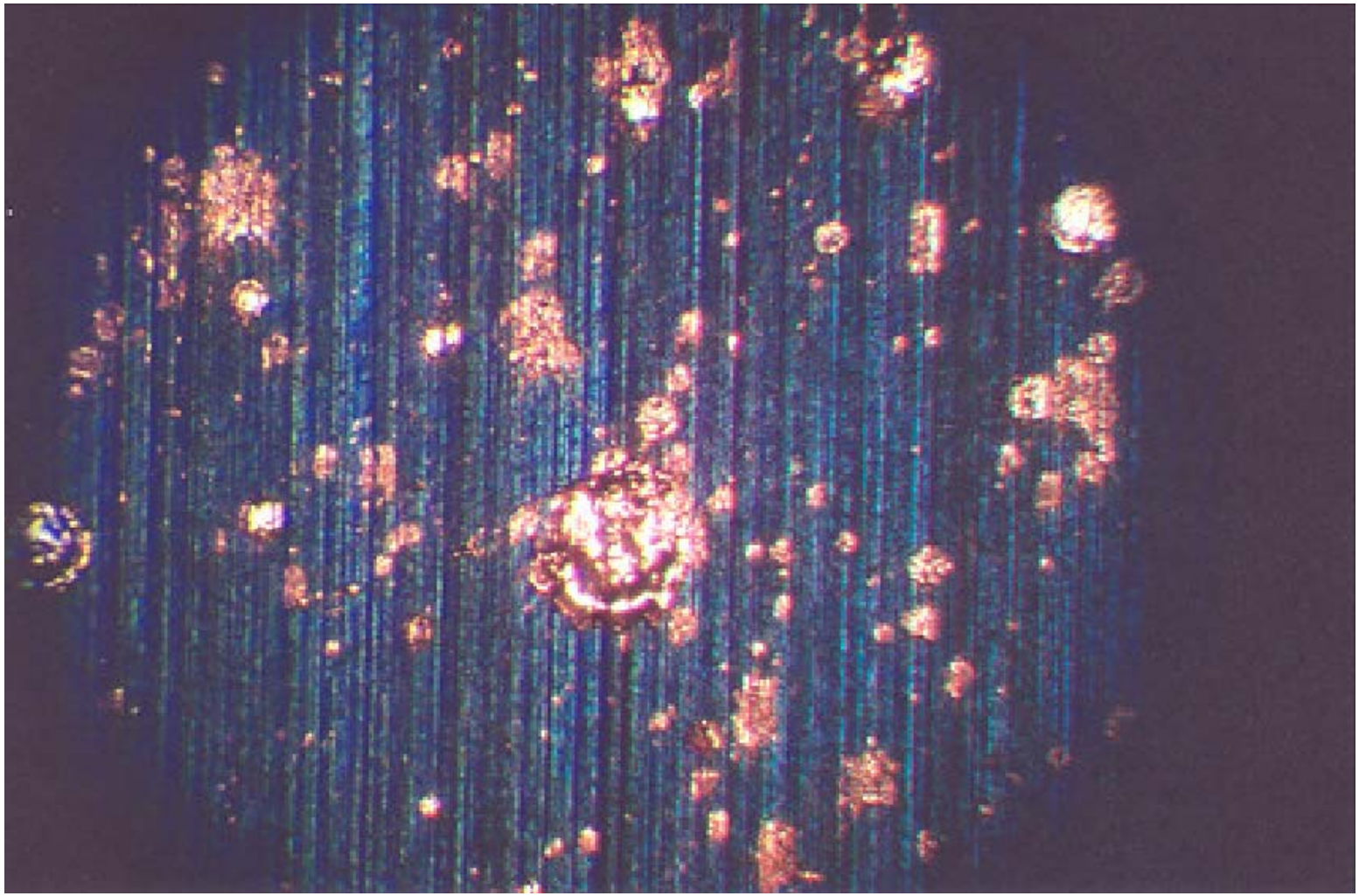
But Systematics better for larger signal
So Large L/E is desired
But too large L is swamped by mass effect which mimics CP
So Low E is prefered

Bad for Factory with Rate $\propto$ E
Good for Superbeam with Rate flat with E

2) An Interesting Observation at Lab G

Microphoto of Be window survace after run

Be is undamage Cu is from damage elsewhere



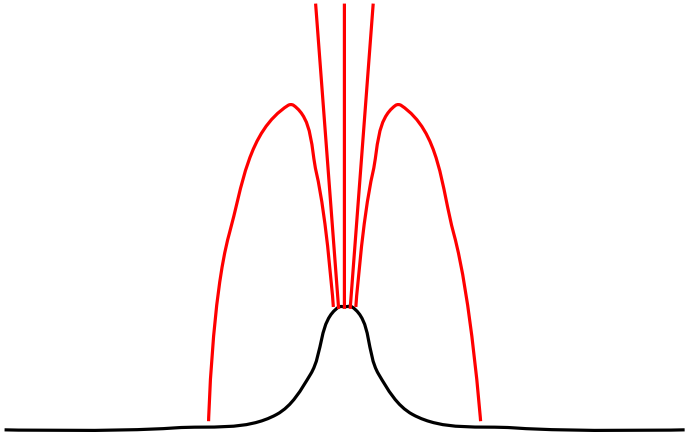
Theory (P. Wilson J. Norem & others)

Three phases of breakdown

1. Spot Plasma
   - Local points break off, or melt from IR heating
   - Removes local high spike
   - Limited lifetime from self-extinction
   - Leads to Conditioning
2. Nearbye melting and crater formation
   - Returning electrons heat and melt a larger area
   - Plasma pressure forms flat area surrounded by wall (crater)
   - Frequency independent (without Magnetic Field)
   - Material dependent
3. Breakdown
   - More complicated
   - But requires #1 and #2 first

#2 Crater Formation

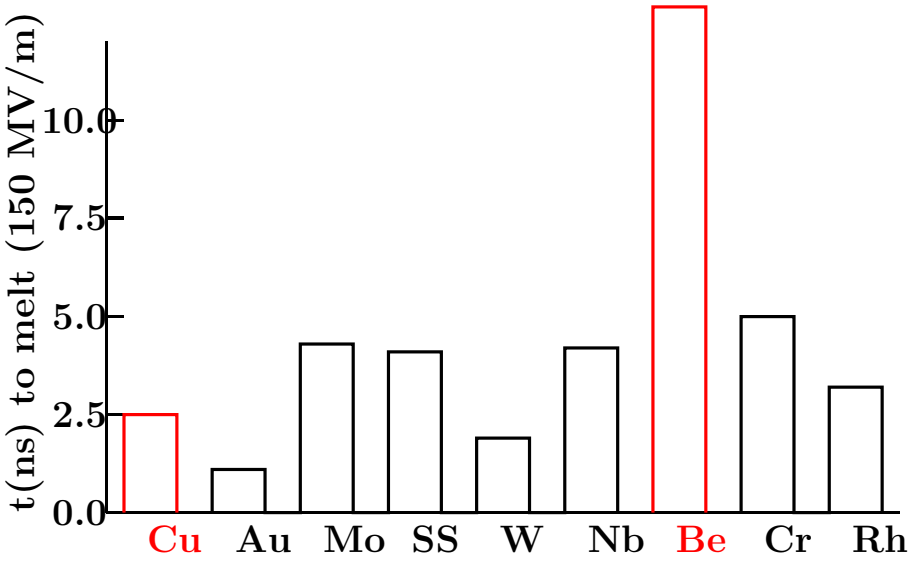
Surrounding area heated
by returned electrons



Magnetic field will guide electrons, concentrating the heating
Effect $\propto$ B/f : Worse for our low freq As observed

Dependence on Material

Deep penetration in Be reduces
rate of temperature rise
As Observed



Try sputtering Be on inside of rest of the cavity
Rolland should try a Be nose

3) Congratualtions to Muon Test Area (MTA) at FNAL

For RF & Absorber tests

Will have:

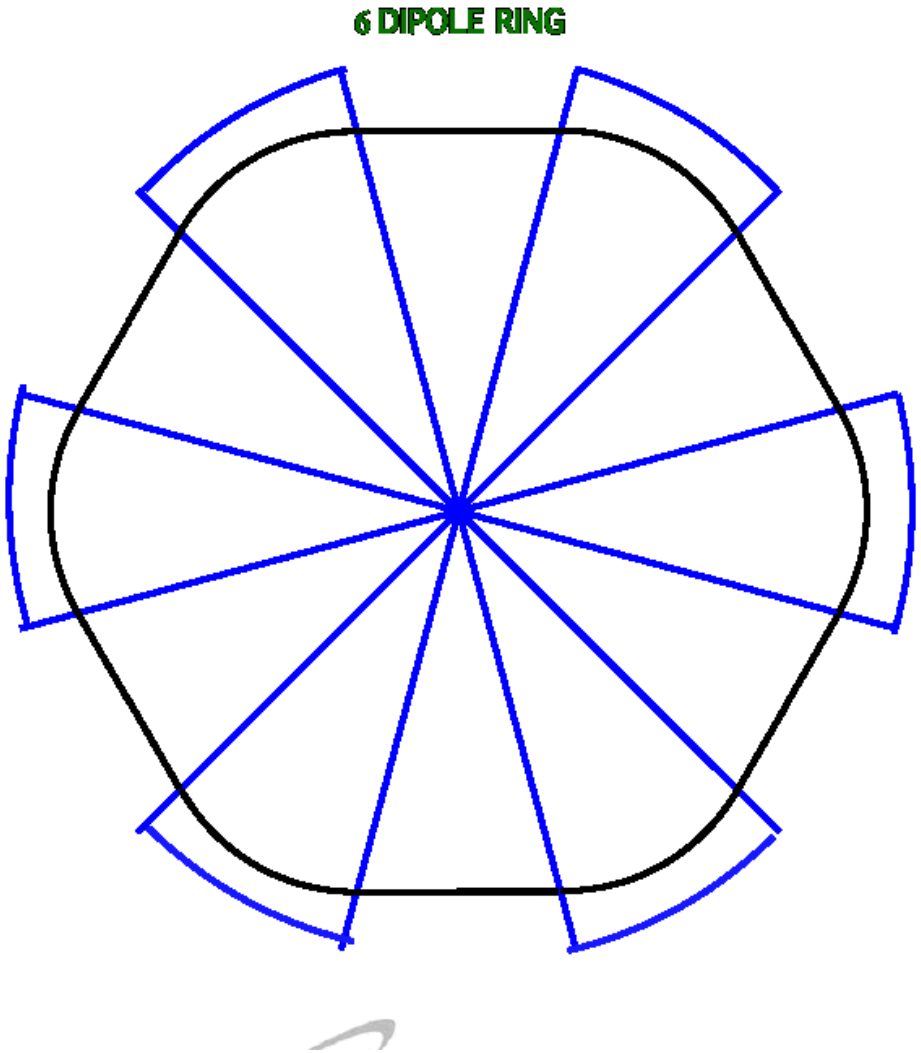
- H2 Cryo for absorber
- He Cryo for solenoids
- 200&800 MHz RF
- p beam for heating

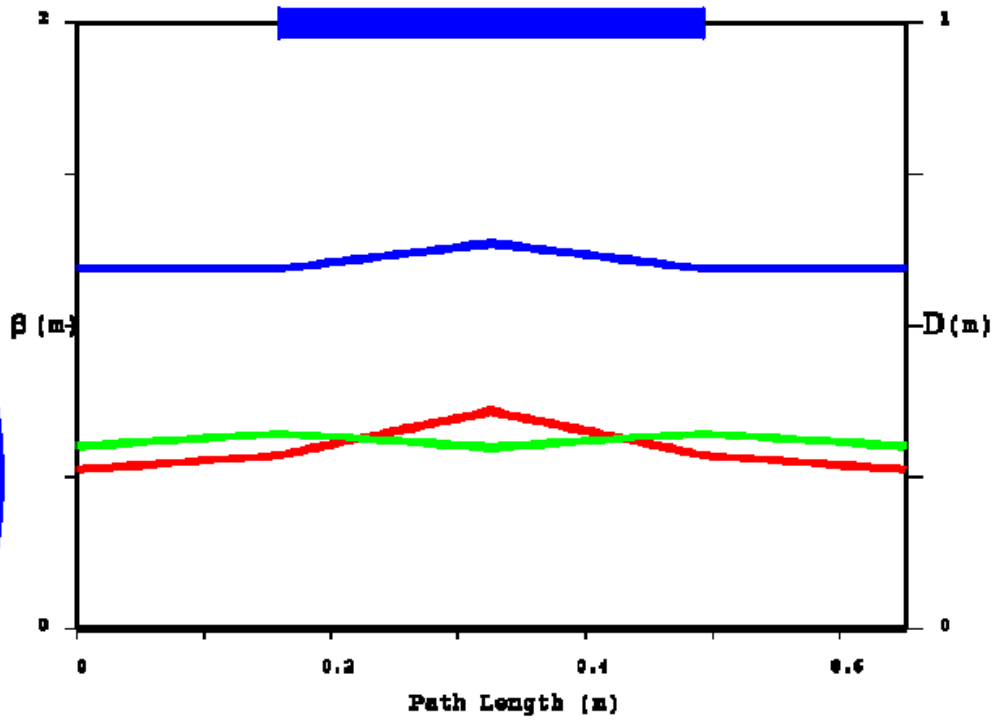
6 months ago

Now

With no Lab G, where would we be if we had not built MTA ?

4) Progress in Weak Focused Cooling Rings





Key parameters at r = 60 cm

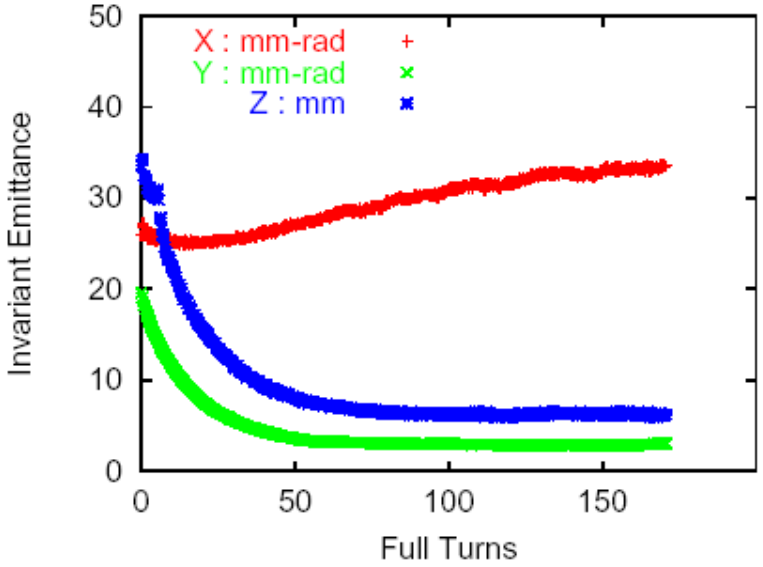
β_x = 53 to 72 cm ; β_y = 60 to 64 cm

Dispersion = 60 to 64 cm

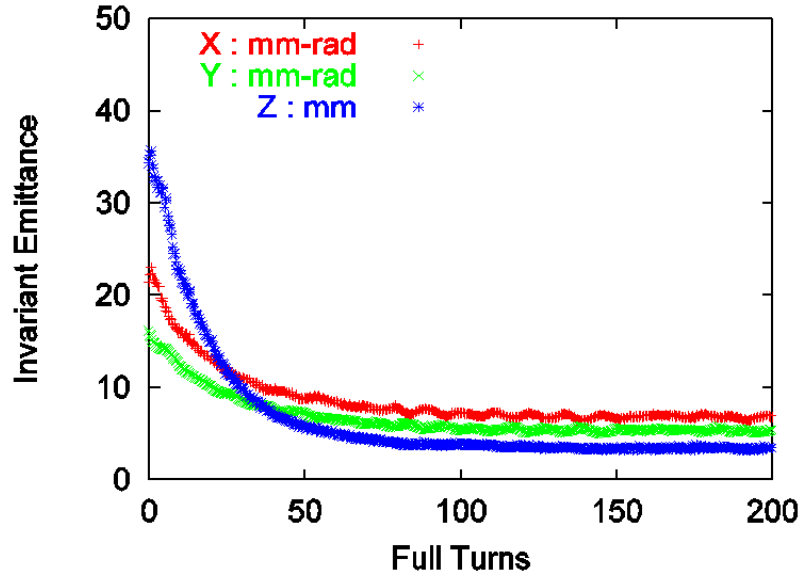
Circumference = 3.91 m

ICOOL Hard Edged Simulation

Without skew quadrupoles



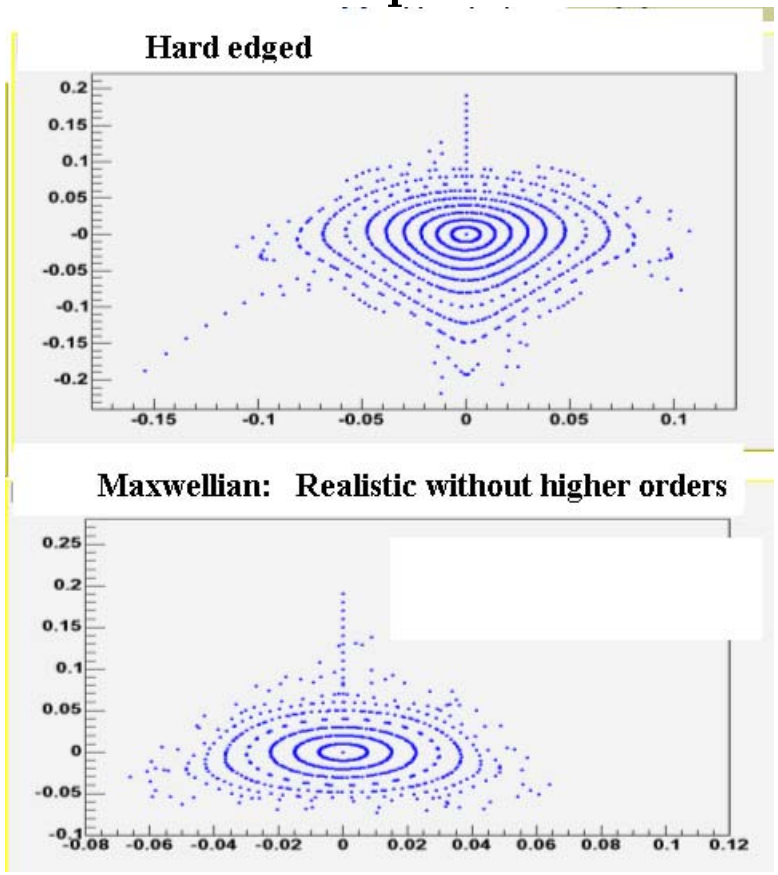
With skew quadrupoles to mix x and y

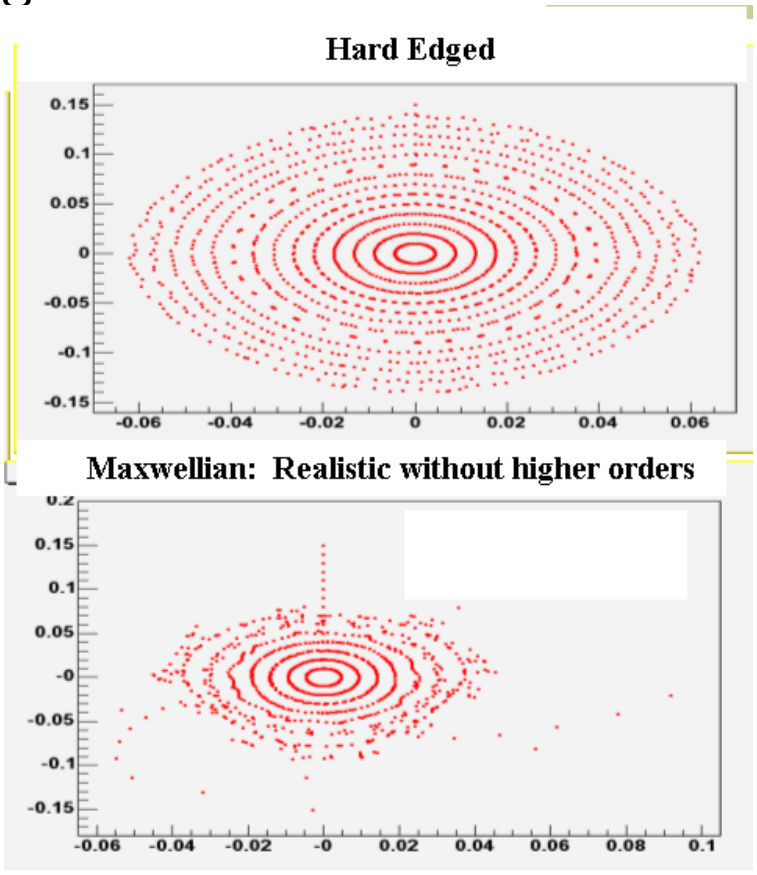


But this is with Non-Maxwellian Fields

Simulation of 4 Pole with Maxwellian Fields (S Kahn)

Fields from simple coils expressed as multipoles and truncated
But the result is a Maxwellian field.
Some coils or pole face could generate it





Only the second ring tracked with Maxwellian Fields Progress
But acceptance (8 x 8 cm) smaller than hard edged (10 x 15)
They should try cooling with this field

Why do I discuss this?

- May be ok with field less than 2 T
  at some price in performance
- Ring is small
- Too small for plausible injection Kicker
- But might be a cost effective 6 D Cooling demonstration
- would see factor > 10, rather than 10%

Does not compete with MICE because

- 6 D rather than 4 D
- Does NOT test components of any real cooling system
- It is far from reality now

Would be a wonderful complement

5) Possible Electron Model of Non-Scaling FFAG

Remember

- Electron AGS Model at BNL
- Electron Scaling FFAG Models at MURA

Non-Scaling FFAG Has Two New Dynamics Phenomena:

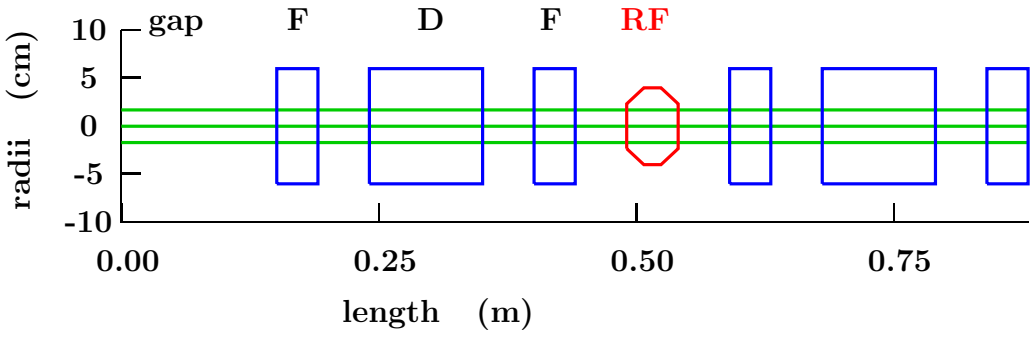
1. Rapid acceleration through integer resonances
2. Acceleration in RF troughs vs. buckets

Both simulated, but need demonstration

US-Japan Collaboration Proposal

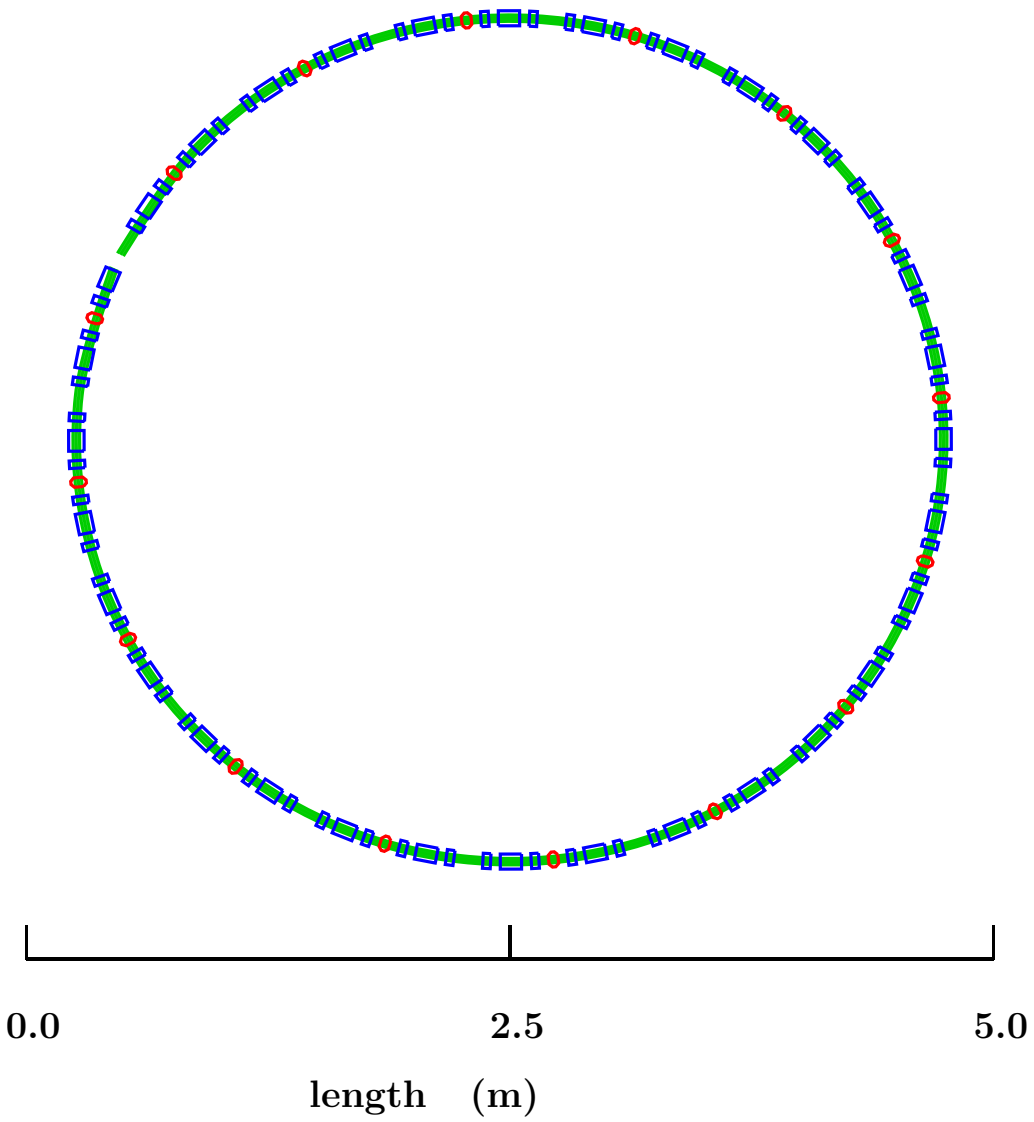
For muon and proton applications

Energy	MeV	10 to 20
Diameter	m	4.5
Peak Mag Fields	T	0.2
Cell length	cm	44
Max Radial Ap	cm	1.7
Freq for mu studies	GHz	3
Freq for p Studies	MHz	21



2 Cells

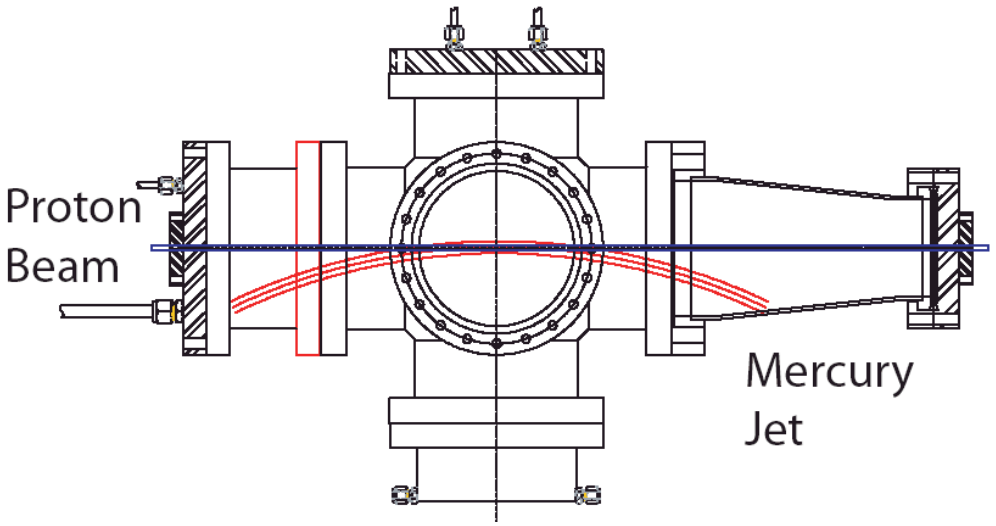
I have to draw a picture

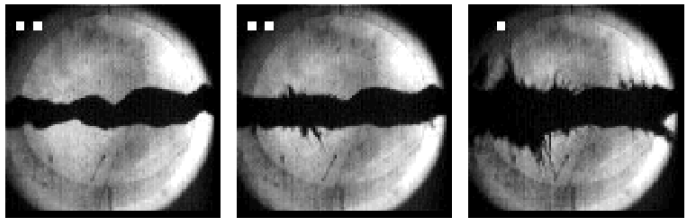


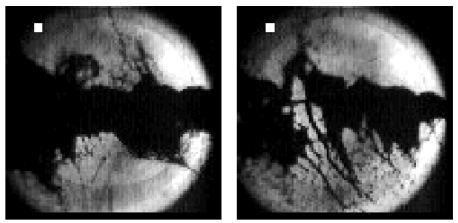
I would make it half the size at 0.4 T (to fit on a table)

6) Possible Target Experiment at CERN

AGS Experiment E951







- **4 Tp/bunch** $(4\ 10^{12})$
  But density equiv to 1 MW
- **Non-Explosive Dispersion**
- **Good Result**

  But No Mag Field

  Low jet velocity

  and compare with:

  1 MW Nu-Factory requires:
  16 Tp/bunch $(1.6\ 10^{13})$

  4 MW Nu-Factory requires:
  32 Tp/bunch $(3.2\ 10^{13})$

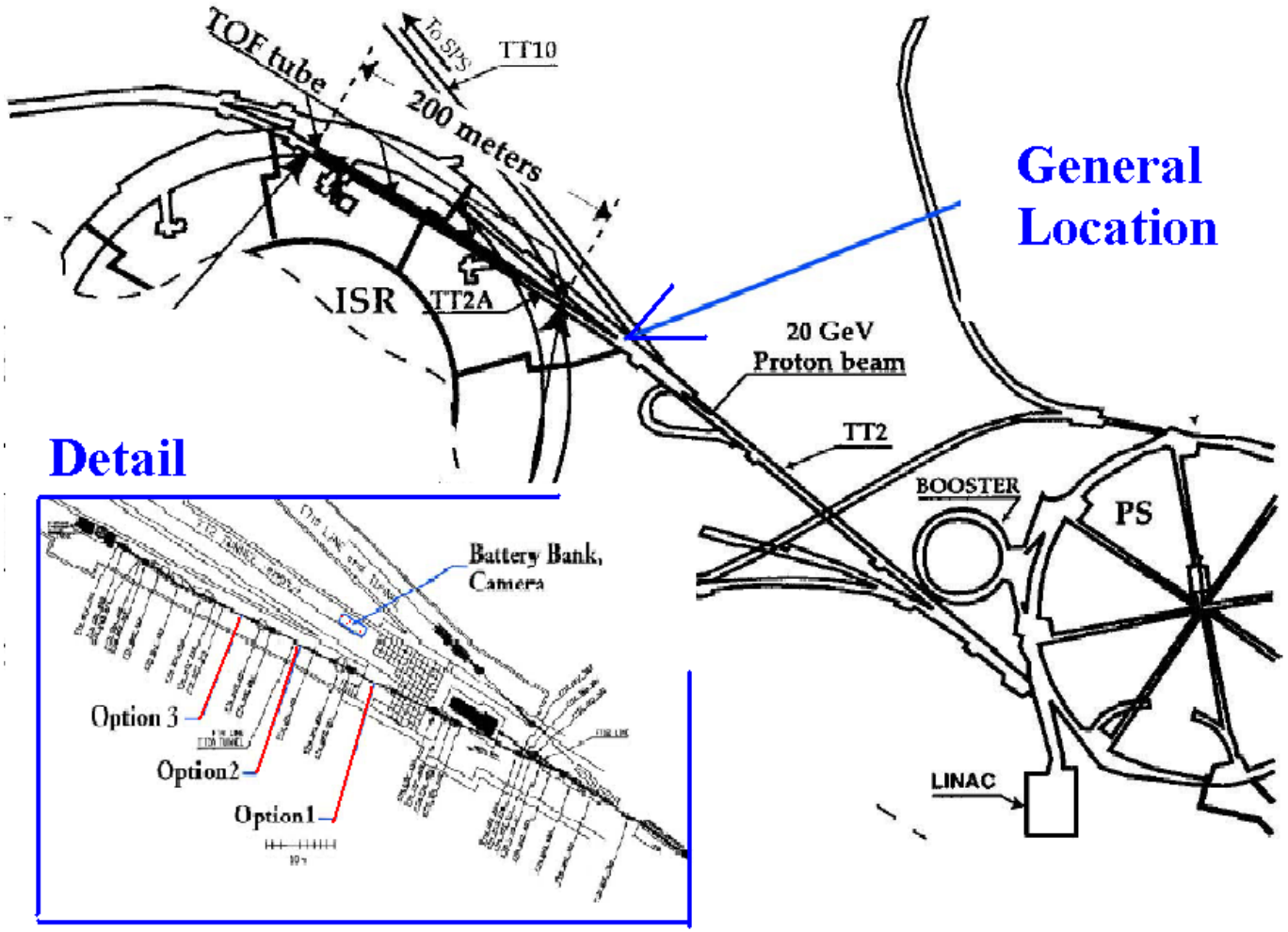
  SO

- **Need further Experiment**
- **More intensity**
- **High velocity jet**
- **magnetic field**

Location for Test

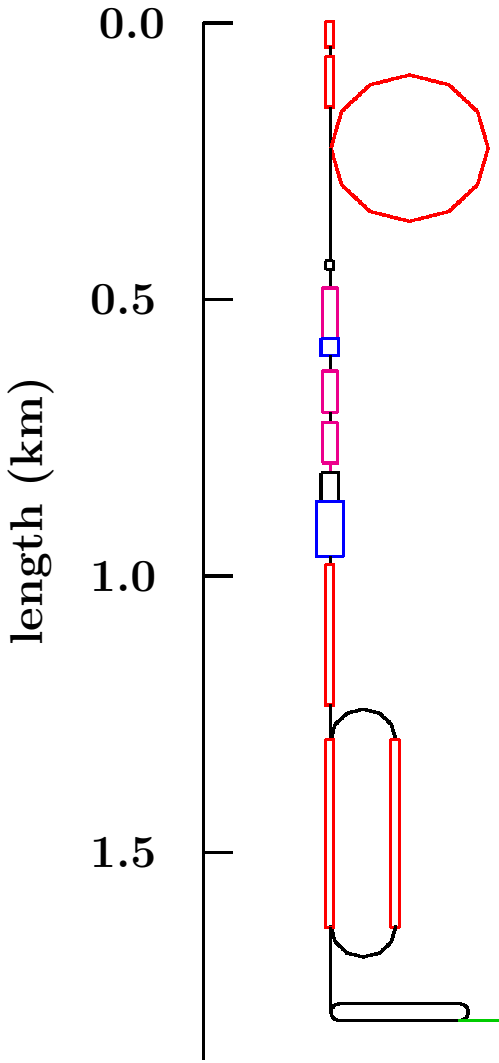
Require 30 Tp for 4 MW Case

- **BNL : 70 Tp**
  - requires full turn extraction (now ≈ 8 Tp)
  - conflict with RSVP
- **JPARC : 300 Tp**
  - not till > 2007
  - but LOI submitted
- **CERN : 30 Tp**
  - Best possibility
  - LOI submitted
  - Proposal soon
  - International



7) Study 2A

Study-2 Schematic



p Driver

Hg Target

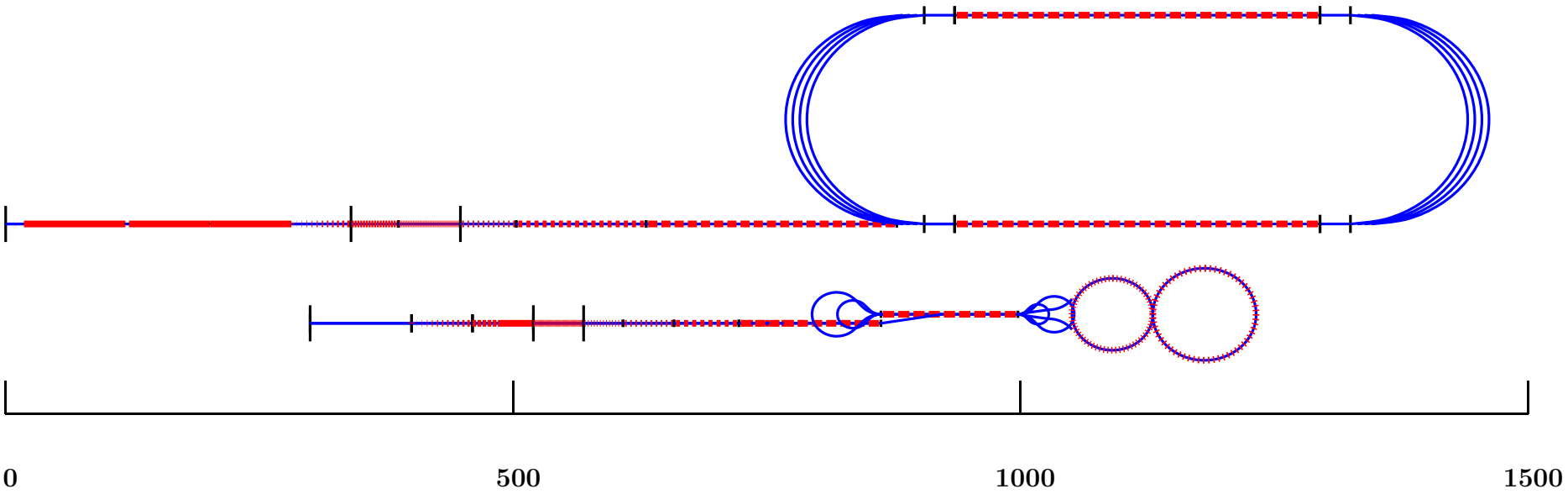
% of 1.8 B$ Cost (no EDIA etc)
without driver or target

Phase Rotation Neuffer Bunch Rotation	(29 %) Substantial saving
Cooling 50 m vs 108 m	(23 %) Substantial Saving
Pre-Acceleration 1.5 GeV vs. 2.5 GeV	(14 %) Savings
RLA Acceleration Dogbone + 2 FFAG's	(26 %) Savings
Storage Ring	(8 %)

Neutrino Beam

Compare New System with Study 2

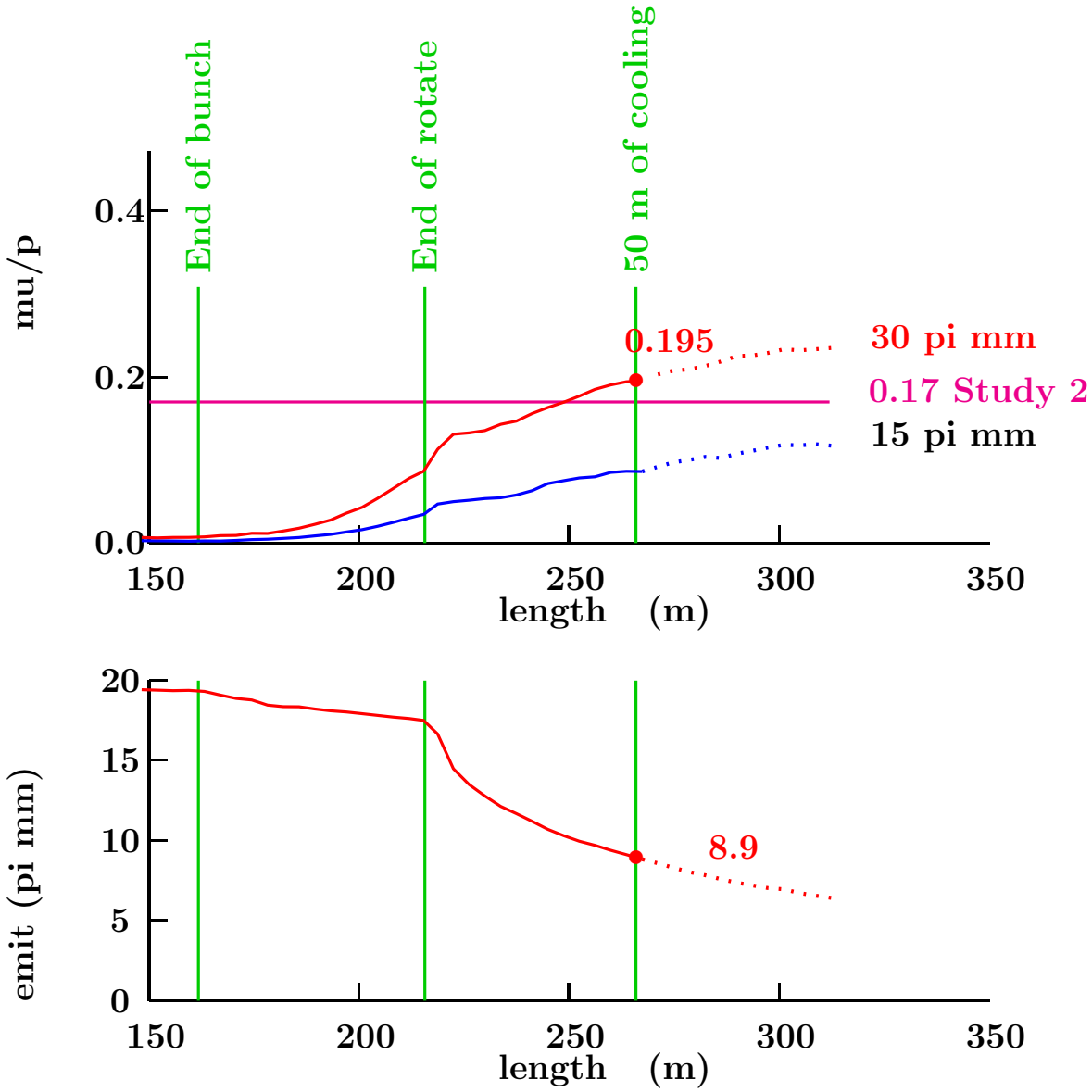
Work in progress: list and draw all needed components



Study	Tunnel m	Beam line m	Hydrogen m	Acceleration m	B dl T m
2	2535	6891	16.0	802	1649
2a	1890	1950	0.0	360	989
	0.75	0.28	0.00	0.45	0.60

Target of "half the cost" not unreasonable

Performance Muons per 24 GeV Proton



- For one sign
  Muons > Study 2
- But both signs captured
- Effectively
  Muons > 2 times Study 2

Conclusion

Where are we now

- Good Design Progress Since Study 2
  - Phase Rotations Without Induction Linacs
  - Larger Acceptance Acceleration
    Including Pre-Acceleration
    Including Compact FFAG Acceleration
  - Lower Cost Cooling Solution
  - Expect Lower Cost and $\geq 2 \times$ Performance

- R&D going well
  - Target Experiment Magnet Under Construction
  - 200 MHz SC Cavity Tested and Being Re-Coated
  - Results from 805 MHz RF in Magnet
  - MTA occupied and nearing use
  - Progress on hydrogen and RF windows
  - 200 MHz Cu RF Under Construction
  - Mice has Scientific Approval

New Priority Needs

- **Simulation for Study 2A**
  - **Match from cooling to Pre-Accelerator**
  - **1.5-5 GeV Dogbone/RLA Arc designs with sextupoles**
  - **FFAG Injection/Extraction**
- **Engineering Design for Study 2A**
  - **LiH/Li Absorbers**
    Existing Absorber group should study this
  - **Kickers for FFAG**
    Easier than for cooling rings, but harder than any existing
- **Continue effort towards a viable cooling ring demonstration**
- **Continue effort towards an electron non-scaling FFAG model (International)**